WIRELESS TECHNOLOGY AND CLINICAL INFLUENCES IN HEALTHCARE SETTING: AN INDIAN CASE STUDY

Abdul Hafeez Baig & Raj Gururajan

School of Information Systems
University of Southern Queensland
Toowoomba, Australia 4350

Corresponding author email:*gururaja@usq.du.au*

ABSTRACT

This chapter argues that current techniques used in the domain of Information Systems is not adequate for establishing determinants of wireless technology in a clinical setting. Using data collected from India, this chapter conducted a first order regrssion modeling (factor analysis) and then a second order regression modeling (SEM) to establish the determinants of clinical influences as a result of using wireless technology in healthcare settings. As information systems professionals, the authors conducted a qualitative data collection to understand the domain prior to employing a quantitative technique, thus providing rigour as well as personal relevance. The outcomes of this study has clearly established that there are a number of influences such as the organisational factors in determining the technology acceptance and provides evidence that trivial factors such as perceived ease of use and perceived usefulness are no longer acceptable as the factors of technology acceptance.

Keywords: Wireless in healthcare, PDA's, Adoption, SEM, Indian Healthcare system, technology adoption, Clinical Influences

INTRODUCTION

In the last few years, high expectations, technological developments, and effective and efficient services have been shown to be prerequisites for improvements in the healthcare domain (Rogoski, 2005; Versel, 2008). Latest trends in the healthcare sector include the design of more flexible and efficient service provider frameworks aimed at providing health services to all stakeholders. In order to implement such frameworks, wireless technology is increasingly being used in the healthcare sector. A decrease in the cost of wireless devices and improved awareness of the benefits by using related wireless applications are two of the

contributing factors towards the increased use of wireless technology in this sector (R. Gururajan, Hafeez-Baig, & Gururjan, 2008; R. Gururajan, Quaddus, Fink, Vuori, & Soar, 2005). Even though the future of this technology and its usability is promising, its adoption is still in its infancy, which is attributed to the complex and critical nature of the healthcare environment. In the current competitive and complex business environment, technology developments have played a critical role in delivering high quality of care (Reinecke, 2004). However, there is limited knowledge and empirical research on the effectiveness and adoption of wireless technology in general, and in the Indian healthcare system in particular.

Recent research has established that investment in emerging Information Technology (IT), including Information Systems (IS), can lead to productivity gains only if they are accepted and effectively used by respective stakeholders. Consequently, acceptance and utilization of IT/IS in the healthcare environment have been central themes in the information systems literature. Therefore, the fundamental focus of this research is to investigate and examine the influence of internal and external determinants on the usefulness of wireless technology. Further, this research also assesses how its acceptance contributes to the adoption of wireless technology. We believe that this research is the first of its kind attempted in the Indian healthcare domain and it employs empirical evidence to explore the impact of wireless technology and its usefulness in the Indian healthcare system. The Indian healthcare domain is at the forefront in adopting the latest medical technologies and applications, as evidenced by media reports and, as such, it constitutes an excellent context for validating existing adoption theories and extending them.

The main contribution of this research includes the identification of a set of drivers and barriers to using wireless technology in a given Indian healthcare setting. In addition to this, for the first time, a set of clinical factors influencing the adoption of wireless technology has been identified and validated using a second order regression model.

LITERATURE REVIEW

The concept of wireless technology in healthcare is discussed in many studies (Dyer, 2003; Hu, Chau, & Liu Sheng, 2002; Sausser, 2003; Simpson, 2003; Siracuse, Pharm, & Sowell, 2008; Versel, 2008; Wisnicki, 2002; Wu & Wu, 2007; Zhang, 2007). For example, Wisnicki (2002) provides details of how broadband technology, an essential component of wireless technology, can be used in healthcare. While prior studies agree that wireless applications have the potential to address the endemic problems of healthcare, very limited information

can be found about the determinants of such applications (Raj Gururajan, Clint Moloney, & Don Kerr, 2005; Raj Gururajan, Toleman, & Soar, 2004). In general, the majority of the works reviewed are descriptive about the benefits of wireless handheld devices in healthcare in general, and medicine in particular. There are only a small number of studies that provide evidence-based information concerning these devices in healthcare (Fischer et al. 2003; Sax et al. 2005)(Hafeez-Baig, 2007). Furthermore, five major studies in the area of healthcare (evaluated by (Spil & Schuring, 2006) testing the Technology Acceptance Model (TAM) produced findings which were inconsistent with the body of knowledge in non-healthcare settings. With 'Perceived Ease of Use' and 'Perceived Usefulness' as the major TAM attributes, these studies found that in the health environment, 'Perceived Usefulness' is an important attribute in technology adoption, while 'Perceived Ease of Use' was found to have no effect (Spil & Schuring, 2006). This is different to findings reported in non-health IS studies, where both attributes were found to be reliable technology adoption predictors. Therefore, further empirical investigation is required to explain the reasons why this variation exists in healthcare. In addition, there is a need to explore if further attributes exist which may influence the adoption of wireless applications in the healthcare environment.

TECHNOLOGY ADOPTION IN HEALTHCARE CONTEXT

In healthcare literature, the discussion on wireless technology falls into three periods. For example, studies prior to and including 2000 discussed the status of wireless technology and the possible role the technology can play in healthcare. Studies between 2000 and 2003 discussed how wireless technology can be deployed in healthcare and the potential benefits the technology can bring to healthcare. It should be noted that these studies were only 'discussion' type studies. Majority of these studies did not provide any empirical evidence as to the use or acceptance of wireless technology in healthcare domains. Studies from 2004 till current date have collected data to establish the usefulness of wireless technology in healthcare. These studies, to some extent have focussed on the PDAs as these devices have been found to be useful in nursing domain for clinical data management.

The studies between 2000 and 2003 discussed a number of potentials of wireless technology in clinical domains. For example, how broadband technology can be used in healthcare was discussed by (Wisnicki, 2002), ability to address prevailing healthcare staff crisis by adopting intelligent solutions using agent and wireless technology that can identify the need and match the need with available resources in a timely and efficient manner was outlined by (Davis,

2002), better compliance with the rigorous regulatory framework was highlighted by (Wisnicki, 2002), reduction in medication errors and hence the benefits that can be realised was discussed by (Turisco, 2000), provision for greater flexibility and mobility of healthcare workers in performing their work was portrayed by (Athey & Stern, 2002), effective management of the increasingly complex information challenges and improved access to those information from anywhere at anytime was discussed by (Stuart & Bawany, 2001). Our review clearly identified that all these studies were only implying the potential of wireless technology and did not provide any empirical evidence.

While prior studies agreed that wireless applications have the potential to address the endemic problems of healthcare, very limited information can be found about the determinants of such wireless applications in order to establish the adoption of technology in a given healthcare context (Raj Gururajan, et al., 2005; Raj Gururajan, et al., 2004). During the period of 2004 – 2006, studies emerged in the area of technology acceptance, specifically focussing on the acceptance of wireless technology in healthcare domains. These studies were empirical in nature and were testing the available models of technology acceptance or a variation in order to ascertain whether previous models hold good for a new technology in a specific domain . These studies were reported in a book titled 'E-Helth Systems Diffusion and Use', published by Idea Group Publishing in 2006 (Spil & Schuring, 2006). These studies are summarised below:

Predicting Internet Use: Applying the Extended Technology Acceptance Model to the Healthcare Environment (Chismar & Wiley-Patton, 2006) – This study empirically established that only perceived usefulness is significant and ease of use was not significant.

The dynamics of IT adoption in a major change process in health delivery (Lapointe, Lamothe, & Fortin, 2006) – This study established that TAM as devised by (Davies, Bagozzi, & Warshaw, 1989) is not adequate for health systems because adoption/resistance factors may be group related as opposed to the fundamental basis of TAM which is individualistic, influence of intra and inter organisational factors, linkages to cultures, environmental factors as well as the complexity of the environment.

Introducing electronic patient records to hospitals: Innovation adoption paths (Suomi, 2006) – This study found that relative advantage, strong network externalities available, rich

availability of information through different communication channels are key factors for innovation and adoption. It should be noted that these are not discussed in the TAM models.

User acceptance and diffusion of innovations summarised (Spil & Schuring, 2006) – This summary established that perceived usefulness is a predictor of technology acceptance in healthcare. Ease of use was not found to be significant.

Understanding physicians' use of online systems: an empirical assessment of an electronic disability evaluation system (Horan, Tule, & Hilton, 2006) – This study found that in order to diffuse technology in an organisation, it is important to ascertain physicians' behaviour, their workflow practices and their perceptions regarding the value of specific information systems.

In essence, the recent studies appear to be indicating that the current models of technology acceptance or its derivatives are not suitable to predict the adoption factors of wireless technology in healthcare environment. Strong support can also be derived from three specific studies that have tested TAM models in healthcare. The first study conducted by (Jayasuriya, 1998) established that ease of use was not significant in a clinical domain. The second study by (Chau & Hu, 2002) echoed similar sentiments. The third study by Hu et al. (Hu, Chau, & Tam, 1999) also found similar findings.

Further, recent studies conducted by (Howard, Gururajan, Hafeez-Baig, & Howard, 2006) also established that ease of use was not significant while determining factors of adoption in a clinical domain in regard to wireless technology. Further, (Ivers & Gururajan, 2006) also found that there are other factors beyond the TAM models influencing the acceptance of technology (Versel, 2008).

Interviews conducted with Queensland nursing staff members in Australia (R. Gururajan, C. Moloney, & D. Kerr, 2005) revealed that Clinical Influences of wireless technology is far more significant than ease of use factor as established in TAM. Another focus group discussion with the Western Australian senior health managers (R. Gururajan, M. Quaddus, et al., 2005) also indicated that aspects of Clinical Influences such as integration of clinical data may be a significant factor than the ease of use factor. (Howard, et al., 2006) also identified Clinical Influences is far more influencing than the ease of use factor while determining factors of adoption of wireless technology in the Indian healthcare domain.

However, the recent findings that the ease of use factor not showing strong significance in healthcare domain while determining wireless technology adoption warrants explanation as this is different to many other reported studies in the generic IS domain where both attributes (ease of use and perceived usefulness) were reported to be reliable predictors.

This variation requires further empirical investigation in order to explain the reason behind this variation specific to healthcare. Therefore, there is a need to identify attributes that assist in the adoption of wireless applications in healthcare environment. We argue that the initial validity of many technology acceptance models was predominantly established by testing the model with students as surrogates in a generic software application domain. This environment is very different to the healthcare environment, where the skills are at different levels. Further, the healthcare environment is complex, sensitive and time critical. These could be some of the reasons why TAM did not perform as expected in healthcare settings.

In addition, in the recent variant of technology acceptance, namely, UTAUT, (Venkatesh, Morris, Davis, & Davis, 2003) reviewed eight prominent models of user acceptance and managed to create a unified view. The unified model comprised of seven constructs. The first four – performance expectancy, effort expectancy, social influence and facilitating conditions – were theorised to be direct determinants. The last three – attitude towards technology, self efficacy and anxiety – were theorised to be indirect. All the seven constructs were found to be significant determinants of technology usage by Venkatesh et al ((Venkatesh, et al., 2003).

In terms of attitude, Venkatesh et al. (Venkatesh, et al., 2003) defined it as an individual's overall affective reaction to using a system. The model depicts four constructs relating to this determinant – attitude towards behaviour, intrinsic motivation, affect towards use and affect. (Spil & Schuring, 2006) verified that in three cases the relation between attitude and behavioural intention is significant. Therefore, this determinant cannot be indirect. If there is significance between attitude and behaviour intention, then there is a direct relationship.

Therefore, there appears to be a basis to identify factors that contribute to the adoption of technologies in healthcare settings. Given that wireless technologies have started making in-roads in healthcare, the overarching purpose of the research is to identify the factors that influence the adoption of wireless technology in the Indian healthcare system. The rationale of the purpose is justified by the fact that India is a leader in software technologies, especially medical applications. Further, India is emerging as 'health tourism', due to the advancement

in medical technology and reduction in cost in offering high quality health services—as highlighted by various print media. However, our initial review of available literature indicated that this area is under-researched. Collectively, these aspects led to the following research question:

> What are the determinants for the adoption of wireless technology by physicians in the Indian healthcare system?

The first stage of this study is focused on answering the research question qualitatively and the second stage on answering the research question quantitatively. Details as to how the research question was answered are provided in the research methodology section below.

METHODOLOGY

An examination of existing IS studies indicated that there is a necessity for a suitable research method. Most of the reviewed studies follow a quantitative approach which involves an instrument being administered onto a domain with perhaps a lesser understanding of the domain issues. For this study it was felt that if technology issues are to be studied with respect to a specific domain, then user involvement with the technology issues forms a major part in establishing the adoption (or inhibiting) factors. By necessity, this would occur prior to administering quantitative instruments (e.g. survey). This, in turn, requires an understanding of research philosophy, values of inquiry that would guide the study, and the choice of relevant research techniques required to conduct the investigation in order to answer the research questions.

Further, there appears to be limited information available in the Indian IS domain to guide the principles of this study. This study is relatively new and, hence, requires a rigorous justification as to the choice of research methods employed. We also believe that due to aspects associated with various regulatory issues impacting the Indian health system, unique factors of technology acceptance, as well as usefulness, may emerge. Our initial meetings with Indian physicians also suggested that there is a divide in terms of technology usage between private and public hospitals, where private hospitals are rich in technology use and public hospitals are not. On the other hand, in many traditional studies in IS, either quantitative or, to some lesser extent, qualitative methods are used—but not both. In recent years this has been cited as a weakness (see (Mingers, 2001) for a detailed argument on this).

Taking this into account, this study investigates the suitability of both approaches in order to answer the research question.

We recognise that the foundation for any research will be grounded on the researcher's fundamental philosophical view of the world (Myers, 1997). The choice of tools, including research techniques, instruments, and methods such as qualitative and quantitative, are not inherently linked to a particular philosophical position, as these positions are generic in nature. It is the contextual framework within which they are applied that provides consistency to an inquiry. While the choice of tools and methods are not linked to the philosophical view, the articulation—which is commonly the process of explaining choices of research methods and its related choice of research instruments—helps determine the philosophical disposition. This is usually achieved by asking questions on the beliefs, perceptions, experiences, advantages and disadvantages in order to determine this disposition. This may even include a researcher's personal experience within that domain, or their expertise in explicating the information using any approach that may be suitable to that domain. This has prompted us to follow a qualitative approach as the first phase of the study. We argue that this approach facilitates direction to the second phase of the study where quantitative evidence can be collected to establish causality between the dependent and the independent variables.

The research question dictates the need for quantitative research methods, while the behavioural component of the same investigation dictates qualitative research methods. The rationale for this approach is based on the notion that behavioural components require a thorough understanding of how users apply wireless technology in a given setting in order to understand behavioural issues. To extract 'tacit' aspects, this is best accomplished by applying a qualitative approach. A quantitative instrument can then be developed to extract the quantitative aspects, such as the opinion scores.

Health professionals view the term 'wireless technology' in different ways, either as a product or a process. The combined domain of wireless technology and healthcare is relatively new in the Indian IS domain. While IS studies have discussed the impact of Information & Communication Technology (ICT) tools and associated behavioural intentions on healthcare users, limited information can be found as to how the combination of wireless technology and healthcare settings would influence users who are already conversant with novel and advanced medical technologies (Spil & Schuring, 2006). The workplace or organizational factors that influence such combinations are yet to be explored in detail. Such

an exploration has close association with the choice of research method as these methods pave the way for proper inquiry into the factors that determine technology acceptance in a given setting. On this basis, the suitability of one research method over another has to be carefully weighed. Consequently, this study identified an exploratory approach to be suitable for the initial investigation. This approach is particularly favourable in confirming the direction of the study, variables chosen for the study, and in helping refine the literature. The exploratory study can also possibly eliminate some variables, while providing opportunities for including emerging variables.

QUALITATIVE DATA COLLECTION

As argued, for the first stage of this research the investigators used a qualitative approach to collect initial sets of themes for the adoption of wireless technology in the Indian healthcare system. For this purpose, 30 physicians operating in Indian healthcare were identified randomly. These physicians were interviewed by an independent member (external to the team) who identified the attributes for the adoption of wireless technology by physicians in the Indian healthcare system. This approach was deliberate to address criticisms of 'bias' in the interview process. Further, due to linguistic issues, we required a person with proficiency in both Indian language and English. The interview questions were derived from existing literature. The first stage of the data collection concentrated on Indian hospitals with some form of wireless technology already in use. The physicians were also chosen based on their wireless technology awareness or working experience. They were drawn from both private and government hospitals. The interviews were conducted over a 45-60 minute period and recorded using a digital recorder. Once they were recorded, the interviews were transcribed.

QUANTITATIVE DATA COLLECTION

This study developed a survey instrument from the interview data. The main reason for this digressed attitude was that previously tested instruments in the technology domain were not relevant to healthcare setting and were found to be inadequate in answering the research question. The data from the interviews were used to develop specific ranges of questions to gather a more detailed view from the wider population. This survey instrument was pilot tested to capture the information reflecting the perceptions and practice of those adopting the wireless technology in the Indian healthcare system. Particularly, it focussed on what internal and external environmental factors affect the adoption of wireless technology and the extent of this influence. The survey was then distributed to over 300 physicians randomly chosen

from the telephone book and a total of 200 responses were received. The survey responses were then entered into a spreadsheet file. A Visual Basic interface was written to generate numerical codes for various elements of the survey for data analysis using SPSS. The coded spreadsheet file was then copied onto a SPSS file format.

DATA ANALYSIS

Qualitative data was analysed using the NVivo (version 7) application, which helped identify the initial themes from the interviews. Quantitative data were analysed using SPSS, which helped identify the factors and their correlation for the adoption of wireless technology in the Indian healthcare setting.

Qualitative Data Analysis

Qualitative data was manually coded to extract themes that had an impact on wireless technology acceptance as stated by the physicians. In total, 63 themes were extracted from the interviews. The initial themes include awareness, cost factors, advantages and disadvantages, medical errors, information sharing, current state of technology, usefulness and role of wireless technology, and technology awareness. On the basis of the interviews and the literature review, the themes were classified into drivers and inhibitors as shown in the following table. This list of drivers and inhibitors was expected to provide a direction for the development of the survey instrument for the collection of quantitative data to capture the wider community views and to generalize the outcome of the research. This grouping is presented in Table 1.

Table 1: The factors driving and inhibiting wireless technology adoption in healthcare

Drivers	Barriers
Save-time	Legal barriers
Improve-clinical-workflow	Administrative purpose
Efficiency-in-communication	Communication with physicians
Delivery-of-high-qual-info	Patient education
Better-quality-of-service	Communication with colleagues
Save-effort	Obtain lab results
Improve-clinical-performance	Note taking
More-contact-time-with-patients	Electronic medical records
Improved-delivery-of-information	Device usage barrier
Reduce-overall-cost	Benefit evaluation barrier
Positive-impact-on-patient-safety	Resource barrier
Reduce-inaccuracies	Electronic prescribing
Improve-public-image	
Reduce-medical-errors	
Easy-access-to-data	
Attract-more-practitioners	
Reduce-workload	

The content of the Table 1 is consistent with findings of previous studies conducted by Gururajan et al. (2004; 2005). This prompted conducting a quantitative study in order to establish causality among dependent and independent variables, as well as external validity and generalisability.

Quantitative Data Analyses

In order to ensure statistical reliability, suitable tests were run on the entire instrument, as well as selected group of variables. For example, the reliability test returned a Cronbach alpha value of 0.965 for the instrument indicating high reliability (Zikmund, 1994). We ran this test because the instrument was generated from the interview data and, hence, it was necessary to establish statistical reliability. In addition, reliability tests were also run for three factor groupings, namely, drivers, inhibitors of adoption and other technology factors. The reliability tests returned values of 0.941, 0.447 and 0.536, respectively, indicating that the data were suitable for factor analysis testing.

As a second step, survey data were analysed for factor analysis using SPSS. It is evident from the table below that two factor component matrix identified drivers and the barriers for the adoption of wireless technology in the Indian healthcare setting. This finding is consistent and aligned with the findings of the qualitative data collection stage (i.e. first stage) of this research.

Table 2: Driving & inhibiting of wireless technology adoption in healthcare from data analysis of survey result

Drivers	Loading values	Barriers	Loading values
Improve-clinical-workflow	.798	Poor technology barrier	.605
Tech-support	.764	Time for training barrier	.572
Delivery-of-high-qual-info	.760	Tech expertise barrier	.554
Save-time	.757	Benefit evaluation barrier	.503
Better-quality-of-service	.749	Legal barriers	.465
Save-effort	.743	Solutions barrier	.444
Improved-delivery-of-information	.732	System migration barrier	.442
Efficiency-in-communication	.730	Technical support barrier	.436
More-contact-time-with-patients	.725	Lack of support barrier	.352
Improve-clinical-performance	.702	Device access barrier	.316
More-training	.699	Device comfort barrier	.248
Improve-public-image	.695	Funding barrier	-.225
Easy-access-to-data	.692	Security as barrier	.224
Positive-impact-on-patient-safety	.679	Device usage barrier	.208
Reduce-inaccuracies	.659		
Reduce-workload	.657		
Reduce-medical-errors	.650		
Reduce-overall-cost	.634		
Attract-more-practitioners	.600		
Org-culture	.464		

The drivers identified through this research were further tested for factor groupings through data reduction technique provided by SPSS. The analysis resulted in Table 3.

Table 3: The factors driving wireless technology adoption in healthcare from data analysis of survey result

Descriptions	Organizational	Management	Clinical
Save-effort	.716		
Reduce-overall-cost	.708		
Reduce-inaccuracies	.703		
Save-time	.667		
Easy-access-to-data	.659		
Attract-more-practitioners		.769	
Improve-public-image		.680	
Tech-support		.680	
Reduce-workload			.817
Improve-clinical-performance			.797

The driving factors of adoption yielded three categories of factors, namely, 'organisational', 'management' and 'clinical'. The organisational components include wireless technology drivers that can generate specific benefits for organisations. The management components represent the benefits that healthcare managers can realise using wireless technology. The clinical components encompass clinical drivers of using wireless technology.

A similar factor model was generated for the inhibitors. The model resulted in Table 4:

Table 4: The factors inhibiting wireless technology adoption in healthcare from data analysis of survey result

Descriptions	Technology	Resource	Usage
Poor technology barrier	.625		
Time for training barrier	.582		
Solutions barrier	.575		
Benefit evaluation barrier	.528		
Tech expertise barrier	.527		
System migration barrier	.511		
Funding barrier		-.749	
Resource barrier		-.690	
Technical support barrier			.542
Device usage barrier			.519

Similar to the drivers, the inhibitors also resulted in three specific categories. The 'technology' category includes technology factors that inhibit wireless adoption in the Indian healthcare. The 'resource' category encompasses resource barriers that are currently being encountered in the healthcare setting. Finally the 'usage' category is comprised of inhibiting factors, which are associated with usage issues.

In addition to the two factor groups, namely drivers and inhibitors, we also identified a third. We named this 'Clinical Influences' and its components are shown in Table 5 below.

Table 5: The factors 'Clinical Influences' of wireless technology adoption in healthcare from data analysis of survey result

Descriptions	General Communication	Clinical Communication	Records Management
Obtain lab results	.837		
Administrative purpose	.770		
Electronic prescribing	.670		
Medical database referral	.632		
Patient education		.727	
Communication with colleagues		.707	
Communication with patients		.676	
Drug administration		.596	
Communication with physicians		.548	
Electronic Medical Records			.764
Generating exception list			.738
Note taking			.617
Disease state management			.563

This factor group yielded three components. The first component deals with the general communication aspects facilitated by wireless technology in healthcare settings. The second component refers to clinical communication using wireless technology. The third component is specific to records management. In summary, the data analyses yielded three specific categories of factors which can affect the adoption of wireless technologies in the healthcare setting. These comprise adoption drivers, inhibitors, and Clinical Influences.

HYPOTHESES FORMULATION AND TESTING

Based on the evidence collected, the three sets of factors, namely, drivers, barriers and Clinical Influences, contribute to the acceptance of wireless technology in healthcare. We hypothesise that the drivers positively impact on Clinical Influences', whereas the barriers have a negative impact on it. While the drivers and barriers include factors beyond the technology aspects, their respective influences are restricted to the clinical domain as this is where the usefulness of wireless technology can be experienced. Therefore, the following two hypotheses were generated for testing:

H1: Drivers of wireless technology positively impact on "Clinical Influences".

H2. Barriers to wireless technology negatively impact on "Clinical Influences".

A "Structural Equaction Modeling (SEM) model was developed in order to test the hypotheses. The rationale for using SEM includes: SEM is used for confirmatory factor analysis (CFA); the pattern of loadings of items on the latent constructs is explicit; SEM provides strong convergent and discriminant validity; p-value of t-value is significant (over 0.50 level) for constructs; and measurement items load highly on theoretically assigned factors and not highly on other factors.

SEM MODEL DEVELOPMENT

In order to develop the SEM model, an AMOS version 16 was used. Initially, the individual drivers, barriers and "Clinical Influences" were tested for CFA (Confirmatory Factor Analysis) scores and these were found to be reliable. When the CFA was found to be satisfactory, a model was built with clinical influences as dependent variable on drivers and barriers. The final outcome is shown in Figure below.

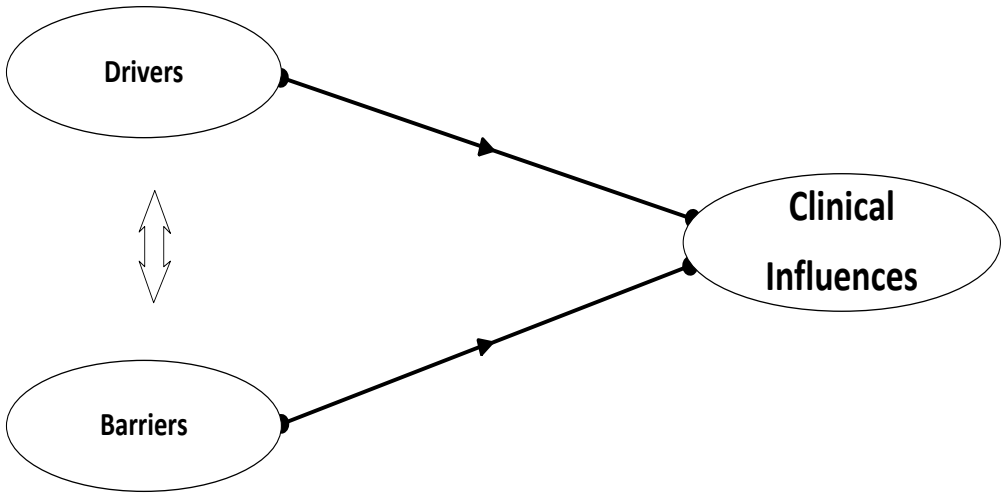

Figure 1: Initial model

Figure 8 shows that the factor loading (the number on the path: for example, for the construct Drivers, has 0.16, 0.21, and .48). The drivers and clinical influneces load highly (over 0.8 for most of the items), indicating a high reliability. Further, all variables have a t-value of over 2.0 to indicate high convergent validity.

Upon construct validation, a simple SEM (consolidated) model was developed to test the hypotheses. The model consists of clinical influneces as the dependent variable, and drivers ("Organizational" (O), "Clinical" (C), and "Management" (M)) and barriers ("Usage" (U), "Technology" (T), and "Resources" (R)" (M) as independent variables. The model was run

with AMOS Graph program and the screenshot shown in Figure 2 displays the values along the link from Drivers to Clinical Influences, and Barriers to Clinical Influences.

Table 6: Description of items used in building the SEM model and their reliability

Variables	Initial	Descriptions	Reliability
Drivers	D1	Reduce-workload	**0.885**
	D2	Improve-public-image	
	D3	Improve-clinical-performance	
	D4	Attract-more-practitioners	
	D5	Save-time	
	D6	Save-effort	
	D7	Tech-support	
	D8	Reduce-overall-cost	
	D9	Easy-access-to-data	
Barriers	B1	Funding barrier	**0.539**
	B2	Resource barrier	
	B3	Solutions barrier	
	B4	System migration barrier	
	B5	Benefit evaluation barrier	
	B6	Time for training barrier	
	B7	Poor technology barrier	
	B8	Tech expertise barrier	
	B9	Technical support barrier	
	B10	Device usage barrier	
clinical influneces	CI 1	Electronic medical records	**0.850**
	CI 2	Medical database referral	
	CI 3	Electronic prescribing	
	CI 4	Obtain lab results	
	CI 5	Disease state management	
	CI 6	Adminstrative purpose	
	CI 7	Generating exception list	
	CI 8	Patient education	
	CI 9	Note taking	
	CI 10	Drug administration	
	CI 11	Communiation with physicians	
	CI 12	Communication with colleagues	

According to (Holmes-Smith, 2000) to analyse a model for the data fit, the following five measurements need to be analysed carefully:

1. Chi-square (X^2 acceptable fit: $p > 0.05$)
2. Normed Chi-square (X^2/df acceptable fit $1 < X^2/df < 2$)
3. Goodness-of-fit index (GFI- acceptable fit value, $0.95<GFI<1$, reasonable fit value would be $0.90<GFI<0.95$)
4. Tucker-Lewis Index (TLI- acceptable value; $TLI>0.95$; reasonable value of fit $0.9<TLI<0.95$ and lack of model parsimony would be $TLI>1$)
5. RootMean-Square Error of Approximation (RMSEA- acceptable fit value: $RMSEA<0.05$; reasonable level of : $0.05<RMSEA<0.08$)

Above criteria was used to analyse the data fit for each of the construct before computing the composite variables. Figures below show the values of each variable separately for initial model and the improved acceptable model for each of the composite model.

Data reduction and technique for Compatibility Variable

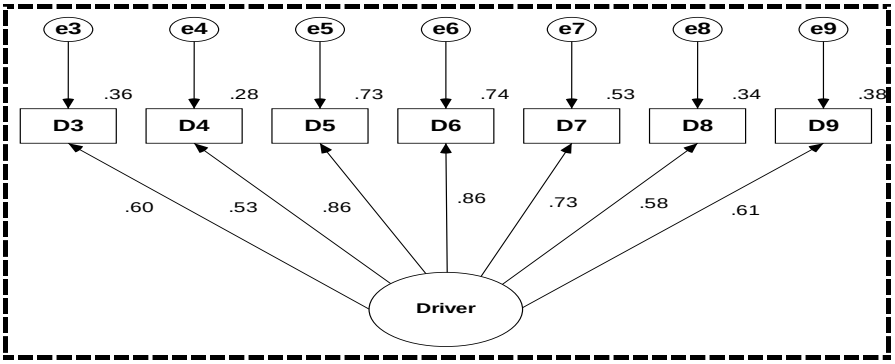

Figure 2: Drivers: $X^2 = 27.5$, df = 14, p = 0.017, $X^2/df = 1.964$, GFI = 0.961, TLI = .963 RMSEA = 0.070 (Data fit the improved model)

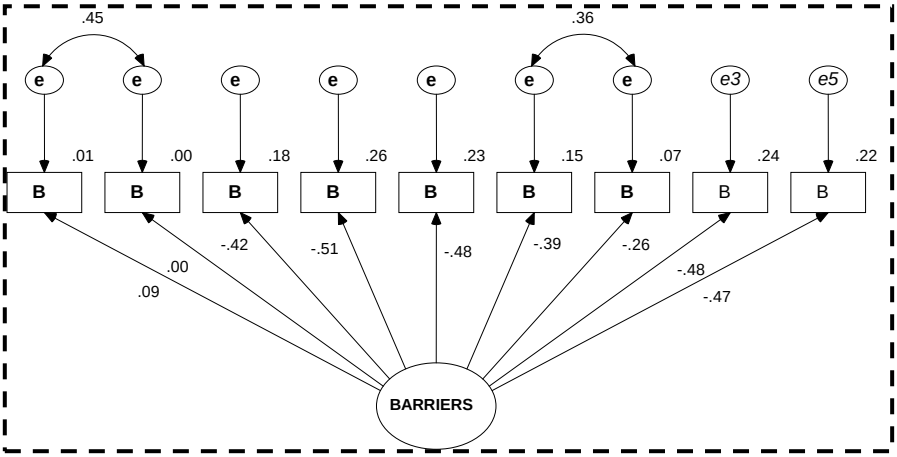

Figure 3: Drivers: $X^2 = 37.3$, df = 25, p = 0.054, $X^2/df = 1.492$, GFI = 0.959, TLI = .900, RMSEA = 0.050 (Data fit the improved model)

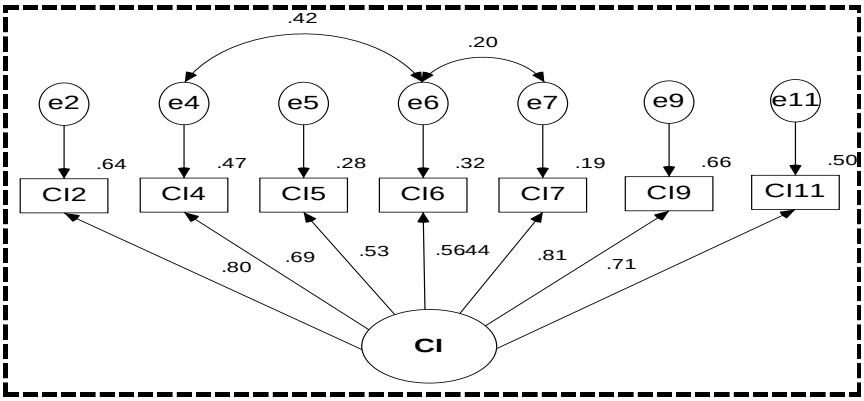

Figure 4: Clinical Influences: $X^2 = 30.8$, df = 12, p = 0.054, $X^2/df = 1.492$, GFI = 0.959, TLI = .900, RMSEA = 0.050 (Data fit the improved model)

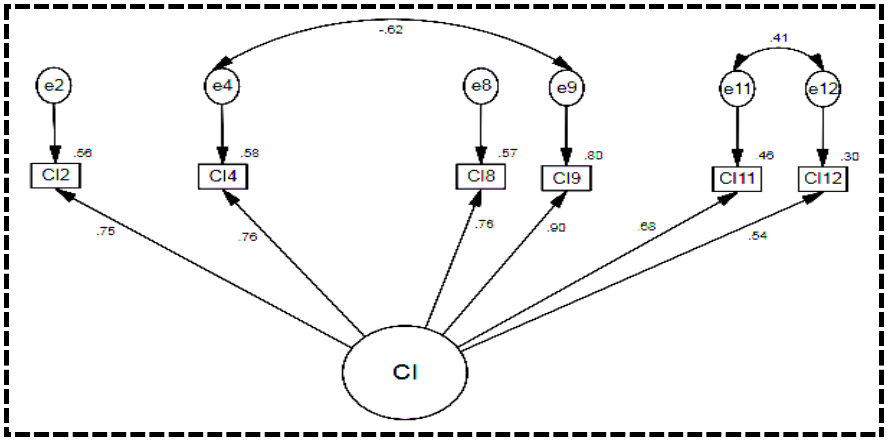

Figure 5: Clinical Influneces: X^2 = 9.0, df = 7, p = 0.252, X^2/df = 1.28, GFI = 0.986, TLI = .992, RMSEA = 0.038 (Data fit the improved model)

Diagram 1, 2 and 3 above shows the data fit for the improve model. This was achieved by appropriate after the analysis of the suggestions provided "Modification Indies" provided by SEM along with the analysis of the adequate theoretical support. Objective was to achieve the improved measure of data fit for the empirical data while keeping integrity of the theoretical support. Results shows that changes in the model has resulted all the five indicator showed that empirical data fitted the improve measurement model.

Once the data reduction techniques was used to individual variables and data was found to fit as per (Holmes-Smith, 2000) incies, we draw the initial SEM model with Barriers (B) and Drivers (D) as an independent variables and clinical influneces (CI) as dependent variable in the model.

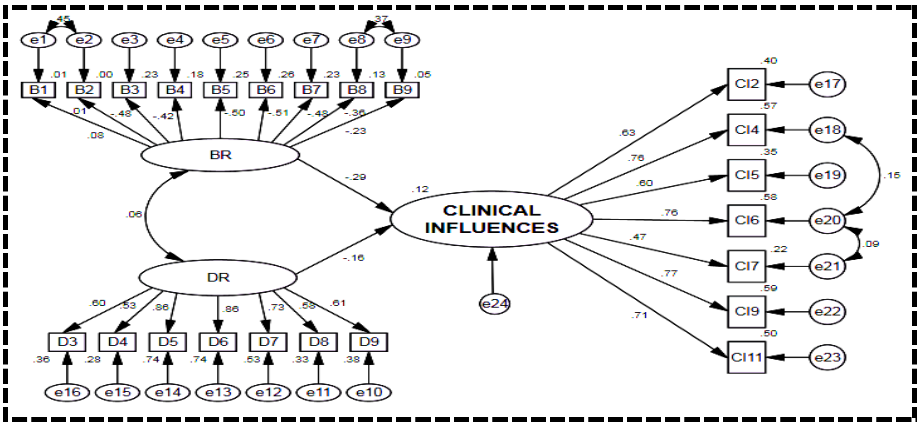

Figure 6: SEM Initial Model: X^2 = 548.0, df = 202, p = 0.000, X^2/df = 2.713, GFI = 0.817, TLI = .755, RMSEA = 0.094 (Data did not fit the improved model)

As can been seen from the above figure 4 above five of the popular measured provided by (Holmes-Smith, 2000) is provided under the diagram. First two values (Chi-square, and

Normed Chi-square) were not at acceptable level, however values of other three (Goodness-of-fit index, Tucker-Lewis Index, and RootMean-Square Error of Approximation) were not at acceptable level. It was concluded that the data did not adequately fit the model.

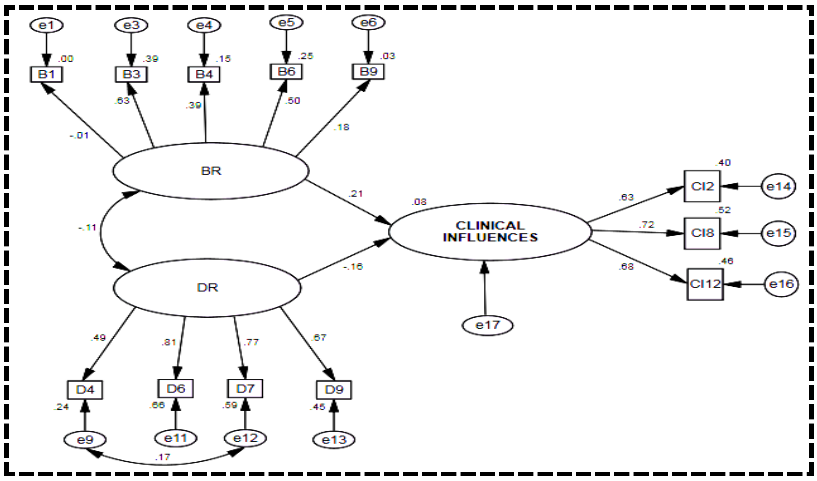

Figure 7: SEM Model: $X^2 = 78.9$, df = 50, p = 0.006, $X^2/df = 1.577$, GFI = 0.939, TLI = .910, RMSEA = 0.055
(Data fit the improved model)

Diagram 5 above shows the data fit for the improve model. This was achieved by appropriate after the analysis of the suggestions provided "Modification Indies" provided by SEM along with the analysis of the adequate theoretical support. Objective was to achieve the improved measure of data fit for the empirical data while keeping integrity of the theoretical support. Results shows that changes in the model has resulted all the five indicator showed that empirical data fitted the improve measurement model.

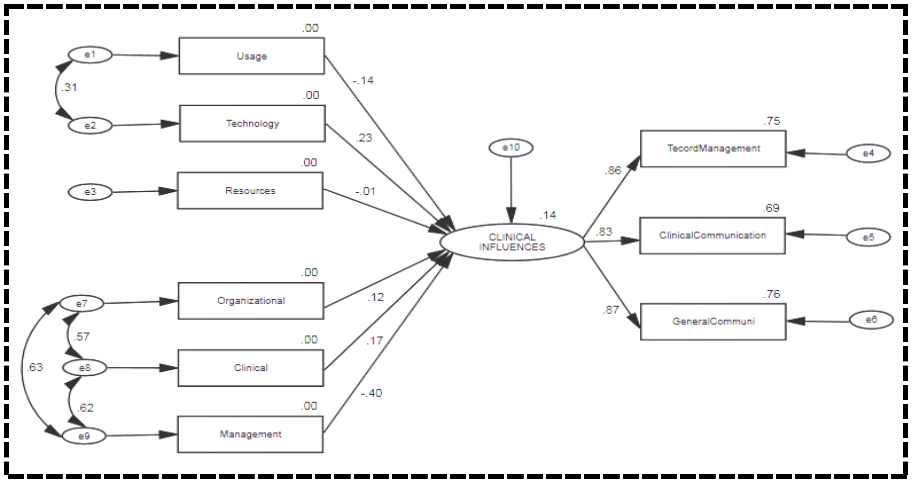

Figure 8: SEM Model: $X^2 = 41.6$, df = 23, p = 0.010, $X^2/df = 1.810$, GFI = 0.955, TLI = .932, RMSEA = 0.065
(Data fit the improved model)

The diagram in the above figure provide the visual results of aggregating the items of the measurement model of stage two of the process, which provided the evidence for the data fit

the model for the empirical data. As a result we produced a composite variable for "Drivers", "Barriers", and "Clinical Influences" in the complete model for the existing data in order to analyse the influence of drivers and barriers on the clinical influences. Data fit of the model and the indices measures are $X^2 = 41.6$, df = 23, p = 0.010, $X^2/df = 1.810$, GFI = 0.955, TLI = .932, and RMSEA = 0.065.

In the above diagram, the latent variable "Clinical Influences" (CI), set of possible predictors, "Usage" (U), "Technology" (T), "Resources" (R), "Organizational" (O), "Clinical" (C), and "Management" (M) are the observed variables. CI is itself indicated by three items, "Technological Management" (TM), "Clinical Communication" (CC), and "General Communication" (GC). As can be seen, the overall structural model fit was good. Criteria used to determined: $X^2 = 41.6$, with 23 df, $X^2/df = 1.810$, CFI = , AIC = , GFI = 0.955, TLI = .932, and RMSEA = 0.065, . Based on these results we proceeded to test the two hypothesis mentioned above (H1, and H2) previously proposed. These hypotheses stated that drivers have positive impact and barrier have negative impact on the clinical influneces. The result supported theses hypothesis, for example in the case of drivers, "Organizational, (t=1.56, $p > 0.01$)", "Clinical, (t=2.14, $p < 0.01$)", and "Management, (t=4.4, $p < 0.01$)" shows that clinical and management drivers are positively contributing to the Clinical Influences, where as the contribution of organizational is not significant. Whereas barrier have vary limited scope, "Usage, (t= -1.98, $p > 0.01$)", "Technology, (t=3.13, $p < 0.01$)", and "Resources, (t= -0.685, $p > 0.01$)". Drivers and barriers are the predictive of the Clinical Influences; results indicate that drivers have stronger influence on the Clinical Influences of the wireless technology than the barrier.

DISCUSSIONS

The Confirmatory Factor Analysis agrees with the outcomes derived from the interview qualitative data in that the set of drivers, barriers and clinical influences are indeed the determinants of wireless technology in the Indian healthcare. Within these three determinants, we are able to identify usage, technology and resources influencing the Clinical Influences. The predictor 'usage' is influenced by the usefulness of technology as identified in recent studies. This study also conforms to the notion that 'ease of use' is not a major influence on technology adoption in the Indian healthcare.

In terms of Clinical Influences, we are able to assert that record management, clinical communication and general communication to be the three major aspects. Our qualitative

study had already given us some indication to these predictors. Our interviews revealed that the greatest benefits of wireless technology in clinical settings would be records management because it is possible for clinicians to access patient data at the point of care. We also understood that it is possible to use smart phone type technology to send patient conditions to other clinicians in order to get advice. In terms of general communication, our interview transcripts indicate that it si now possible to provide patient education using the wireless technology.

Thus, wireless technology can be used to facilitate access to clinical information and communications between clinicians, maximise clinician time, increase patient safety, and accomplish the strategic and business goals of health organisations. Taken together, these factors have a direct impact on Clinical Influences and its effectiveness. However, achieving Clinical Influences with wireless handheld devices can be a challenge and has several implications.

Firstly, the highest security standards must be achieved. This includes direct end-to-end data encryption, authentication, authorisation, maintenance of audit logs and session management (Chen et al. 2004). While high security standards are essential, their implementation is likely to affect usability. For example, the download and encryption of patient information from the server where it is stored into a wireless handheld device may not be prompt. Sax et al. (2005) argue that clinicians may experience increasingly longer time lags when they carry out increasingly more complex procedures. This is likely to adversely affect Clinical Influences and, hence, decrease user acceptance.

Closely associated with security is also the issue of patient confidentiality, which is of significant importance and concern. Although wireless handheld devices have locking security features and password protection functions which activate during periods of inactivity, the frequent use of these functions during the clinicians' busy daily schedules may have an impact on Clinical Influences.

A crucial lesson learnt in this study was in the use of qualitative and quantitative components. We approached the healthcare professionals to seek their opinions on the benefits of using wireless technology. This stage was followed up with a survey instrument. We conducted a first order regression analysis to regress the 90 or so factors explored into a set of manageable factors. The lesson was quite valuable because as outsiders (coming from an Information

Systems background), we were able to appreciate the complexities of healthcare information systems. Similarly, our open minded approach enabled healthcare professionals to appreciate IS related aspects. We also found out through our informal discussions that the study would have been a stereo-type study had we approached a quan-qual type mixed method because we would have been restricted by what was available in the literature to derive our quan part and this would have restricted our qual part.

To our own surprise, we found both IS and health literature to be limited in catching up with wireless technology related attitude and perception data. While the technology literature such as the IEEE provided us with the technical knowledge, human aspects have not yet been discussed in IS and healthcare literature. The results established through a second order regression are consistent with what we found for the Australian Healthcare (published elsewhere).

We measured only perceptions and attitudes in this study. While there is sufficient information available through interviews on the type of savings and benefits that can be attained by using wireless technology in healthcare, it is still not clear as to the exact quantification of these. Therefore, it would be useful to measure this by employing a wireless technology in a clinical setting and then collecting some evidence as to the savings and benefits.

In essence, the study has clearly identified a number of organisational factors and context factors influencing technology adoption in a clinical setting, rather than merely identifying trivial factors. The factors identified in this study are drawn from the experiences and oipinions of clinical professionals who are current with their profession and who are involved in critical yet timely decision making. Thus, teh factors identified in this study add value to administrators of healthcare settings.

REFERENCES

Athey, S., & Stern, S. (2002). The impact of information technology on emergency health care outcomes. *RAND Journal of Economics, 33*(3), 399 - 388.

Chau, P. Y. K., & Hu, P. J.-H. (2002). Investigating healthcare professionals' decision to accept telemedicine technology: An empirical test of competing theories. *Information and Management, 39*, 297-311.

Chismar, W. R., & Wiley-Patton, S. (2006). Predicting Internet Use: Applying teh Extended Technology Acceptance Model to the Healthcare Environment. In T. A. M. Spil & R.

W. Schuring (Eds.), *E-Health Systems Diffusion and USe: The Innovation, the USer and the USE IT Model*. London: Idea Group PUblishing.

Davies, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Communications of the ACM, 35*(8), 982-1003.

Davis, R. (2002). Pursue front end solutions to revenue problems. *Healthcare Financial Management, 56*(8), 30 - 36.

Dyer, O. (2003). Patients will be reminded of appointments by text messages. *British Medical Journal, 326*(402), 281.

Gururajan, R., Hafeez-Baig, A., & Gururjan, V. (2008). *CLINICAL FACTORS AND TECHNOLOGICAL BARRIERS AS DETERMINANTS FOR THE INTENTION TO USE WIRELESS HANDHELD TECHNOLOGY IN HEALTHCARE ENVIRONMENT: AN INDIAN CASE STUDY*. Paper presented at the 16th European Conference on Information Systems, National University of Ireland, Galway.

Gururajan, R., Moloney, C., & Kerr, D. (2005). *Drivers for wireless handheld technology: views from Queensland nurses*.

Gururajan, R., Moloney, C., & Kerr, D. (2005). *Drivers for wireless handheld technology: views from Queensland nurses.* Paper presented at the Australian Business & Behavioural Sciences Association (ABBSA) Conference, Cairns, Australia.

Gururajan, R., Quaddus, M., Fink, D., Vuori, T., & Soar, J. (2005). *Drivers and Barriers to adoption of wireless handheld system in WA healthcare: Selected views.* Paper presented at the HIC 2005, Melbourne.

Gururajan, R., Toleman, M., & Soar, J. (2004, 25-27 July). *Necessity for a new technology acceptance model to predict adoption of wireless technology in healthcare.* Paper presented at the Let's Make a Difference with Health ICT, HIC Conference.

Hafeez-Baig, A. (2007). *Technology Management, Data management, Improved outcomes, Efficiency and Software limitation influencing the use of wireless technology for healthcare in Pakistan* Paper presented at the 6th IEEE/ACIS International Conference on Computer and Information Science (ICIS 2007) Melbourne.

Holmes-Smith, P. (2000). Introduction to Structural Equation Modeling Using AMOS 4.0: Course Notes. Melbourne, SREAMS.

Horan, T. A., Tule, B., & Hilton, B. N. (2006). Understanding physician use of online systems: An empirical assessment of an electronic disability evaluation system. In T. A. M. Spil & R. W.Schuring (Eds.), *E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model*
London: Idea Group Publishing.

Howard, A., Gururajan, R., Hafeez-Baig, A., & Howard, S. (2006). *Clinical Usefulness of Wireless Technology in Healthcare: An Indian Study.* Paper presented at the The Australasian Conference on Information Systems, University of South Australia.

Hu, P. J., Chau, P. Y. K., & Liu Sheng, O. R. (2002). Adoption of telemedicine technology by health care organisations: An exploratory study. *Journal of organisational computing and electronic commerce, 12*(3), 197-222.

Hu, P. J., Chau, P. Y. K., & Tam, K. Y. (1999). Examining teh technologya cceptance model using physician acceptance of telemedicine technology. *Journal of Management Information Systems, 16*(2), 91-112.

Ivers, B., & Gururajan, R. (2006). *Management issues in telecommunications: videoconferencing & telehealth.* Paper presented at the International Conference on Recent Trends in Information Systems Proceedings, India.

Jayasuriya, R. (1998). Determinants of microcomputer technology use: Implications for education and training of health staff. *International Journal of Medical Informatics, 50*, 187-194.

Lapointe, L., Lamothe, L., & Fortin, J. (2006). The dynamics of IT adoption in a major change process in healthcare delivery. In T. A. M. Spil & R. W. Schuring (Eds.), *E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model*. London: The Idea Group Publishing.

Mingers, J. (2001). Combining IS research methods: Towards a pluralist methodology. *Information Systems REsearch, 12*(3), 240-259.

Myers, M. D. (1997). Qualitative research in Information Systems. *MIS Quarterly, 21*(2), 241-242.

Reinecke, I. (2004). Managing Information in Health. Melbourne National Health Information Summit.

Rogoski, R. (2005). Wireless by Design. *Health Management Technology*(January), 1-7.

Sausser, G. D. (2003). Thin is in: web-based systems enhance security, clinical quality. *Healthcare Financial Management, 57*(7), 86-88.

Simpson, R. L. (2003). The patient's point of view -- IT matters. *Nursing Administration Quarterly, 27*(3), 254-256.

Siracuse, M. V., Pharm, D., & Sowell, J. G. (2008). Doctor of Pharmacy Students' Use of Personal Digital Assistant. *American Journal of Parmaceutical Education, 72*(1), 1-7.

Spil, T. A. M., & Schuring, R. W. (2006). *E-Health system Diffusion and Use*. Hershey: IDea Group Publishing.

Stuart, D., & Bawany, K. (2001). Wireless Services: United Kingdom: Gartner.

Suomi, R. (2006). Introducing electronic patient records to hospitals: Innovation adoption paths. In T. A. M. Spil & R. W.Schuring (Eds.), *E-Health Systems Diffusion and Use: The Innovation, the User and the USE IT Model*. London: Idea Group Publishing.

Turisco, F. (2000). Mobile computing is next technology frontier for health providers. *Healthcare Financial Management, 54*(11), 78 - 82.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. (2003). User Acceptance of Information Technology: Toward A Unified View. *MIS Quarterly, 27*(3), 425-478.

Versel, N. (2008). Use of Mobile and Wireless Technology Jumps in Hospitals. *Digital HealthCare,* from http://www.digitalhcp.com/DigitalHealthCare_Content.aspx?id=72018

Wisnicki, H. J. (2002). Wireless networking transforms healthcare: physician's practices better able to handle workflow, increase productivity (The human connection). *Ophthalmology Times*, *27*(21), 38 - 41.

Wu, K., & Wu, X. (2007). *A Wireless Mobile Monitoring System for Home Healthcare and Community Medical Services.* Paper presented at the Bioinformatics and Biomedical Engineering, 2007. ICBBE 2007. The 1st International Conference on.

Zhang, D. (2007). Web content adaptation for mobile handheld devices *Communications of the ACM 50*(2), 75-79.

Zikmund, W. (1994). *Business Research Methods* (International Ed. ed.). Orlando, FL: The Dryden Press.